References/Documentation for Indoor Air Concerns (as of 9/9/99) by H. Schuver

There has been a fairly significant amount of discussion of indoor air concerns related to soil and groundwater contamination lately (following Colorado's presentation at the RCRA National Meeting in Jan.) and during the last EI Issues call a number of individuals requested more hard references and documentation of sites and contacts supporting the concern for indoor air quality being impacted by contaminated soils and groundwater. An individual from the NJDEP recently called with the same request.

Most of the requests are for publications about the Colorado sites, however, although the sampling of indoor air in CO has been taking place for over three years, and remedial systems have been installed in approximately 27 homes and 5 apartment buildings (at the CDOT site alone), there has been no time left over to publish these results, by regulators (or evidently, interest by the responsible party). The Colorado Dept. of Public Health and Environment has, over the last year, lost 44% of its corrective action staff (from a "high" of 6.8, lost 3, now 3.8 FTE for the entire state of CO (8 sites were recently returned to R8 lead (including two with significant indoor air concerns)).

This file is intended to help satisfy this need for more hard references and documentation of sites and contacts supporting the concern for indoor air quality (that we are aware of at the present time, and as thoroughly as resource limitations permit).

The references (that I am aware of) will be presented in approximately chronological order, along with how it can be obtained, and a brief commentary if I was able to obtain it. This is followed by a skeleton of a list of sites with significant concerns for indoor air quality (call participants are encouraged to forward information on additional sites to have this list become more accurate picture of the sites with significant concerns for indoor air impacts). A list of other (not previously mentioned) indoor air contacts concludes this file.

References for Indoor Air Impacts:

1987 Experiments on Pollutant Transport from Soil into Residential Basements by Pressure-Driven Airflow, Nazaroff, et. al., Environ. Sci. Technol., 21(5):459-466.

1990 Estimates for hydrocarbon vapor emissions resulting from service station remediations and buried gasoline contaminated soils. Johnson, Hertz, & Beyers, In Petroleum Contaminated Soils, Vol. 3. Lewis Pub., Chelsea, MI.

1991 Heuristic model for predicting the intrusion rate of contaminant vapors into buildings, Johnson & Ettinger, Environ. Sci. Technol., 25:1445-1452. This may be the official publication of the model described below.

1991 Johnson-Ettinger Model for Subsurface Vapor Intrusion into Buildings, by Paul Johnson & Robbie Ettinger, (available at the current Superfund Web site "www.epa.gov/superfund/programs/risk/calctools/airmodel/johnson-ettinger.html").

I have not had a chance to download this yet, but these calculation tables allow one to enter some amount (two tiers) of site-specific data and predict indoor concentrations (and risks), as well as back-calculate acceptable soil and groundwater concentrations.

Obviously, this model, which continues to be used, was not created out of the blue and shows (what appears to us to be) a long period of understanding of the mechanisms and import of this transport and exposure pathway. The Superfund web site introduction to the model explains how this model was NOT used in the development of the Soil Screening Levels in 1996 due to the large site-specific variability, but that the use of this model is encouraged at sites where there is a concern over indoor air quality. A user's guide for the model was developed in 1997 (see below).

1992 Transport of Subsurface Contaminants into Buildings, by Little, Daisey, & Nazaroff, Environ. Sci. Technol., Vol. 26, No. 11, 1992, 2058-2066. Pat VanLeeuwen of R5 gave me a hard copy of this 9 page document. The text clearly presents the basic physics and calculations for this route of transport and exposure, and includes some interesting quotes like "The subsurface transport of volatile contaminants into buildings near contaminated sites has been considered an addition route of exposure (7-14), but the overall impact of the pathway has not yet been placed in perspective"[as of 1992].

Additionally, the article concludes with "This work has shown that subsurface transport of volatile contaminants into buildings near contaminated sites and landfills may result in levels of indoor air contamination that are many orders of magnitude higher than typical baseline levels. The associated risks are, in turn, orders of magnitude above acceptable levels." The article includes 41 references.

1992 Assessing Potential Indoor Air Impacts for Superfund Sites, USEPA, National Tech. Guidance Study Series. Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-451/R-92-002. I just received a copy from Janine Dinan of the HQ CERCLA program (it is well over 100 pages in length, with 31 references in App. A) and read through it quickly.

In summary, it lays out a generalized four step assessment procedure, specifically addresses indoor air risk assessment (apparently as an addendum to RAGs Part A), and includes appendices A) Predictive Screening Techniques (models), B) Monitoring Methods (indoor and outdoors), and C) Case Studies (with eight interesting, but dated, cases and approaches).

The four recommended assessment steps are

1) Conduct simple conservative modeling (to estimate the potential magnitude of the exposure).

2) If step 1 suggests a potential problem, conduct more sophisticated modeling.

3) If step 2 indicates potential, conduct exterior monitoring (to confirm model predictions). This step may include screening-level indoor monitoring, if high potential.

4) When necessary, conduct monitoring "at the building" ("to provide the best estimate of site impact on indoor air quality").

Note, the document in general, and specifically the Step 4 text, appears hesitant to even use the terms indoor air monitoring and generally down plays the value of indoor air samples as it goes on to say "It is expected that this [step 4 indoor air] monitoring will typically only provide marginal improvements in the exposure estimates obtainable by following Step 3."

After reading through the introduction and the eight case examples in Appendix C it appears that this hesitancy to rely on (or require?) indoor air samples could be related to the difficulty (at the time, 1992) of distinguishing other sources of air contaminants (however, with improvements like Colo. DPH&E's clear distinction of 1,1-DCE not being from commercial products, high quality household product surveys, TAGA unit verifying the highest indoor air concentrations are at utility-line (floor) entry points, and the possibility for improved correlation of indoor and soil-gases, the hesitancy of using indoor air samples no longer appears justified). However, the general tiered approach to screening sites (for indoor air concerns) remains valid and useful. Some more in-depth description of the screening procedures (and comments) follow:

Step 1) The "first cut" for simple conservative modeling is very simple and could be useful.

If we assume: Diffusivities in air = 10-5
Henry's Law constants = 10-1 (dimensionless)
Air filled and total porosities both equal 0.4
Building air changes per hour = 0.5, and
100 % of the soil gas under building enters.

The equation (from pg 2-4) is simply $IAC = \frac{C_l}{L}$

Where:
IAC = Indoor air concentration, ug/m3
C_l = Concentration in groundwater, ug/L
L = Depth to water table, M.

The text follows with "Note that this is the upper bound concentration for the most volatile component in very porous completely dry soil and should be expected to yield excessively high results for less volatile compound and for tightly packed or wet soils."

However, it is no so clear (to me anyway) that this is completely conservative (since I noted that later in the text (pg C-50) that "The air/water partitioning of the two contaminants was determined using Henry's Law constants at constant atmosphere: PCE, 1.1 x 10+3,; TCE, 5.5 x 10+2 [apparently dimensionless]." and "The larger of the Henry's Law constant, the greater the equilibrium concentration of the compound in air compared to its concentration in water." But this may just be a units problem somewhere (maybe in the equation, since pg C-31 has Henry's Law constants similar to those used in the equation (highest is 10-1 (for 1,1-DCE)) but indicates that these are in units of atm*m3/mol? (it is hard to read). Also, it is not clear to me that the air in all homes completely changes every two hours , i.e., the assumed 0.5 air exchanges per hour, (particularly for those tighter homes built in the energy shortage of the 1970's; which can cause interior concentrations to increase).

Anyway, if we used the"first cut" for simple conservative modeling screening test (IAC = C_l/L) for the CDOT site in Colo. and we inserted their 9/30/98 Corrective Measures Plan 1 x 10-6 Air goal of 0.041 ug/m3 and assumed a depth to water of a convenient (for calculating) 10 meter depth we would solve for a groundwater PRG of 0.41 ug/l. In fact the PRP at the CDOT site developed (based on much more sophisticated modeling of indoor air and "correlation" [to the observed plume conc. apparently]) a 10-6 risk-due-to-indoor-air-based PRG for groundwater of 21 ug/l.

Note that the PRP's correlation-based value for groundwater is only 50 times higher than that predicted from the (reportedly overly) conservative model and the clay rich alluvial soils in the Denver sites are clearly not the clean sands assumed in the model resulting in "Air filled and total porosities both equal 0.4" (and "Diffusivities in air = 10-5"?). A one and one-half an order of magnitude (50x) variation is not much compared to what is possible in different soil types, so at least the remaining assumption of "100 % of the soil gas under building enters" may not be so far from true (at least at this CDOT site).

Step 2) Screening Level 2 Modeling (more sophisticated modeling) is intended to "provide the best estimate that can currently be made without sampling at the structure(s) in question."

A number of models are discussed in the main test and Appendix A, including the 1991 Johnson-Ettinger model described above (for which automated calculation tables are currently available on Superfund's web site) and it is my impression that the J-E model remains, and is, the state of the art for this level of screening. Note, there are still a number of simplifying assumptions and limitations with the J-E models.

Step 3) On-Site Exterior Monitoring is discussed, and appears to generally recommend various methods to verify model predictions (short of indoor samples) including angle boring to obtain soil-gas from beneath the building (not adjacent to the building where atmospheric gases are being pulled under the building by negative interior pressures).

Step 4) Indoor Monitoring is discussed in some depth (although procedures are probably fairly dated by now (e.g., method TO-15 is not mentioned)) and includes numerous recommendations for statistically comparing sample results to "maximum reported concentrations for non-impacted structures" (as some kind of a "background") and other things to keep in mind (apparently) so that nobody becomes too concerned over indoor air results (or at least they are kept in some (agreed upon) perspective).

Appendix C has some interesting case studies and quotes:

Page C-14 "Data from the offsite probes and the monitoring program indicated that the gas had migrated up to approximately <u>2,600 feet from the landfill</u> and was seeping to homes at that distance." This was primarily talking about methane from a landfill and landfills have some unique positive pressure source components, but methane can be a carrier for other gases ("no BTX compounds were found beyond 2,300 feet from the landfill perimeter" pg C-19) and it is pretty interesting that we are talking about gas migration (without a plume source, "The study demonstrated that landfill gas migrated from the site independently from contaminated groundwater" pg C-20) of ½ mile!

This study also "demonstrates the difficulty in preventing soil gas intrusion by retrofit patching of existing buildings [and the effectiveness of soil gas extraction wells]" (pg C-20). "Several residences adjacent to [soil gas] control well installations typically recorded levels of methane above 10,000 ppm despite repeated efforts to seal the foundations of those structures [until the control wells were turned on]"

Page C-30 had some interesting quotes that describes a 2 x 10-3 risk (due to indoor air) as "moderate increased risk" and a 1 x 10-4 risk (due to indoor air) as a "low increased risk." Page C-41 describes a 3.5 x 10-6 risk (due to indoor air) as "no increased risk." These statements are by the Agency for Toxic Substances and Disease Registry (ATSDR) but this text (along with a number of other observations) implies (to me anyway) a historical, and perhaps continuing, tendency for discounting the risks due to environmentally-contaminated indoor air.

It is somewhat difficult to understand why a behavior that is not optional or easily avoided (i.e., breathing), and is one of the most efficient and direct routes for contaminants to enter the body and blood (via the lungs), is (apparently) treated as if it is less important than other exposure pathways. Clearly, there are other (non-environmental (e.g., "consumer products" (e.g., gasoline, paint solvents, cleaning products, dry-cleaned clothes, and chlorinated drinking water) related) sources of indoor air contamination. However, wouldn't education of the public in regards to indoor air risks due to "household products" as a co-incidental effect of addressing environmentally contaminated indoor air be more appropriate than accepting higher risks due to environmentally contaminated indoor air because these same individuals are also (perhaps unknowingly) subjecting themselves to high risks due to air exposures to consumer products? Particularly, when the typical remedial actions (vapor exhaust systems) are low in cost and also address any radon (another major source of inhalation risks) which may be present. Furthermore, if we regulated groundwater (or soil) similarly (and considered 2 x 10-3 risks as only "moderate" increased risks) we would probably be leaving a lot of (inappropriate) contamination out there.

1992 Indoor Air Quality Data Base for Organic Compounds, prepared by contractors in AEERL, Indoor Air Branch, Research Triangle Park, NC for USEPA, ORD. Wash. DC, EPA-600-R-92-025 (PB92-158468). I only have 4 pages (from Colo.) although App. C has at least 39 references.

1994 Calculation of Soil Cleanup Criteria for Carcinogenic Volatile Organic Compounds as Controlled by the Soil-to-Indoor Air Exposure Pathway, Sanders, P.F., and Stern, A.H.: Environmental Toxicology and Chemistry, Vol. 13, No. 8, pp. 1367-1373, 1994.

199? Upward Migration of Vapors, Hartman, In LUST Line Bulletin 27, p. 12-15, available at: www.tegenv.com/tegsd/articles/1127blne.pdf

This is a concise 4-page article describing the transports mechanisms and has some interesting quotes, e.g., with "increased application of natural attenuation ... RBCA ... consideration must be given to the fate and transport of contaminant vapors" and "only modest concentrations in the soil, soil vapor, or water are required to result in room air concentrations that fail the acceptable levels."

1996 An Evaluation of Vapor Intrusion Into Buildings Through a Study of Field Data," Fitzpatrick, N.A. and Fitzgerald, J.J.: Presented at the 11th Annual Conference on Contaminated Soils, University of Massachusetts at Amherst, October 1996; and in Soil Vapor Transport to Indoor Air Workshop, Feb. 6-7, 1997, Brea, CA. This document is discussed on p. 52 of the User's Guide (below) and it is reported that this study concluded the Johnson-Ettinger model "in some cases, may under predict indoor concentrations for chlorinated species." Jenny Wu in R9 has a copy of this document.

1997 User's Guide for The Johnson-Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings, Environ. Qual. Man., Inc. (Craig Mann), prepared for Janine Dinan of USEPA, OERR, Toxics Integration Branch (5202G). Includes 36 references.

This is an excellent and (from what I can understand) full description of the model and its assumptions and limitations. Some of the notable limitations (at least in the Tier 1default values) are: 1) no NAPL (in soils, or any conc. > solubility limit (for only individual constituents) in water; 2) assumes "vapor contaminant entering the structure is instantaneously and homogeneously distributed" through out the air space of the building; 3) floor and wall cracks are assumed to be no greater than 1 millimeter is diameter and only around the perimeter of the building and these are "the only for soil gas entry"; 4) Does "not account for preferential vapor pathways due to soil fractures, vegetation root pathways, or the effects of a gravel layer below the floor slab or backfill which may act to increase the vapor permeability"; ans 5) The model does not consider chemical (biologic of abiotic) transformations (e.g., TCE to DCE).

This last item could be important limitation of the model for constituents like 1,1, DCE found in the Colo. sites. Because the model predictions are all based on single constituent concentrations in water this may not be an accurate basis for predicting vapor concentrations for constituents that do not like to be in water (i.e., they would rather be in vapor). After about the tenth time I heard Ron Simms (of Utah State) discuss the fugacity of 1,1,DCE (that it would rather be in vapor than dissolved (much more so than TCE)) during our CA Workshop, it occurred to me that since TCE is the source of the DCE we should not expect to find high concentrations of DCE in groundwater (because as fast as it forms (from the reduction of TCE) it could be moving rapidly into the vapor phase). And apparently, if this is the case then, the J-E model, which is only based on the DCE conc. in water, would do a very poor job of predicting DCE concentrations in vapors (and associated risks). Unfortunately, even if true, this does not explain everything about the "apparently" low concentrations in the groundwater plume under the Colo. sites (because these concentrations are for total VOCs (confirmed yesterday with Charles Johnson)).

1997 Compendium Method TO-15 (Determination of Volatile Organic Compounds (VOCs) In Air Collected in Specially-Prepared Canisters And Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS) EPA/625/R-96/010b, CERI, ORD, Cincinnati, OH, and related letters by Sheila Gaston (1998) and Edgar Ethington (1999) of Colo. DPH&E.

1998 Indoor Air Corrective Measures Plan - Final, CDOT, available at Colo. Dept. Public Health and Environ., HMWMD-B2, 4300 Cherry Creek Dr. So., Denver, CO, 80246-1530, 15 pg. Includes a table showing an RP derived gw std for DCE of 21 ppb for 10-6 indoor air risks.

1998 Assessing the Significance of Subsurface Contaminant Vapor Migration to Enclosed Spaces, Site-Specific Alternatives to Generic Estimates, API Publication No. 4674, December 1998.

1998 Status of Pre-Mitigation Indoor Air Tests (Preliminary) summary map for CDOT facility, available at Colo. Dept. Public Health and Environ., HMWMD-B2, 4300 Cherry Creek Dr. So., Denver, CO, 80246-1530, 1 pg color map.

1998 RASP Results, (CDOT site) 1996-Present (10/98) tabular data for 1,1-DCE, TCE, 1,1,1-TCA, DCM, Vinyl Chloride, 1,1-DCA, 1,2-DCA, and Survey Results (Number of Children, and Years in Home). 82 pg., available at Colo. Dept. Public Health and Environ., HMWMD-B2, 4300 Cherry Creek Dr. So., Denver, CO, 80246-1530.

1999 Groundwater Contamination and Indoor Air Impacts, Charles Johnson, of Colo. DPH&E, Presentation slides from RCRA National Meeting, Wash. DC, Jan. 1999. 13 pg. Several people have hard copies that could be faxed, as needed.

1999 Draft Amended Compliance Order for Indoor Air Assessment Workplan, contact Edgar Ethington, Colo. DPH&E, includes workplan elements a-o and other language, 18 pg.

1999 EI Issues notes (various files from March - to date) Some of the highlights to date:

Indorair3.wpd (good intro to Colo. issues)
Indorair4.wpd (continuation of Colo. issues)
R2indair.mlm (add. discussion of Colo. details)

Vapor.mlm	(includes web references to UST articles/ models)
Ettinger.mlm	(has web address for J-Ettinger model and other articles)
Narpmair.wpd	(summary of issues for RCRA CA at the time early 8/99)
Vaprb875.mlm	(web address that may have info on a particular site)
Bob1.wpd	(ATSDR's summary of TCE in indoor air at Lowery AFB in Colo.)
Bob2-.wpd	(Colo. DPH&E's response to ATSDR's report)

1999 Vapor Monitoring in Basements Panel, NARPM meeting, Chicago, IL, Aug. 5, 1999. Included presentations by Brad Bradley, Gwen Massenburg, and Pat VanLeeuwen of Region 5, Henry Schuver of OSW, and Turpin Ballard of Region 4; on sites in various Regions.

1999 Upcoming 15th Annual International Conference on Contaminated Soils & Groundwater at the U of Mass., Oct 18-21, with four sessions on indoor air.

Full day - Soil to Indoor Air Vapor Exposure Pathway Workshop,

Recommended Steps to Assess Air Pathway Related Health Risk for Buildings Erected on Contaminated Properties"

Indoor Air Impacts from Contaminated Groundwater Discharging to Sumps in Residential Dwellings in Stoughton, MA - A Case Study, and

Screening Model Simulating Transport of soil Contaminant Vapors into Buildings - Source Lifetime Estimation

(Registration contact telephone number is (413) 545-0172 and general conference information is at (413) 545-1239.)

Initial Draft of

Sites with Significant Concerns for Vapors in Structures
and
Other Indoor Air Contacts List

Region	State	Facility Name	Contact name	Phone	Comp./ Conc.
1	MA	Dry Cleaning Inst.	?	?	PCE?, TCE?
2					
3					
4					
5	IN	Conrail-Elkhart	Brad Bradley	(312) 886-4742	Carbon Tet.
	IN	Himco Dump	Gwen Massenburg	(312) 886-0983	BTEX, PCE, TCE
6					

7	IA	__________	Michael Wei	(515) 281-8707	gw=23 ppm 1,2 DCE
8	CO	Colo.DOT	Charles Johnson	(303) 692-3348	TCE, 1,1, DCE
	CO	Redfield	?	?	TCE?
	CO	Lowrey AFB	Sheila Gaston	(303) 692-3332	TCE, DCE?, VC?
	CO	Schlage Lock	Edgar Ethington	(303) 692-3438	?
9	CA	BKK Landfill	Carmen Santos, R9	(415) 744-2037	DCE, VC,
	CA	GTE	Jenny Wu, R9	(415) 744-2032	TCE, 130,000 ug/m3
	CA	Casmalia Landfill	?	?	?
10					

Other Contacts (who may or may not be available to regulators free of charge)

Robbie Ettinger		An author of Johnson-Ettinger model	
Craig Mann		An author of users guide to " "	(919) 489-5299
Sydny Poole	ODEP	Developing Ohio Vapor guidance	(614) 644-2756
Eric Hagen	ODEP	" " " "	

Regulatory Updates:

I have been told that OR, MA, MI may have soil-gas stds for indoor air impacts.